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(54) Unitary rotors having hollow blades and their manufacture

(57) A unitary rotor having hollow blades (13) is manufactured by providing a rotor disc (11) with projections (25, 41) on its periphery at the positions where the blades are to be fixed to the disc, each projection having an outline shape which corresponds substantially to that of the inside (14) of each blade at its radially inner end (26) and being surrounded by a flat joint surface (27, 43). The end (26) of each blade (13) is fitted over a respective one of the projections (25; 41), and each blade (13) is fixed on the disc (11) by welding the radially inner end surface of the blade defined by the thickness (31) of its walls to the flat joint surface (27; 43). This method of manufacture prevents the formation of a weld bead inside each blade. The projection (41) is formed as a flanged plug member for the hollow blade.

FIG. 2

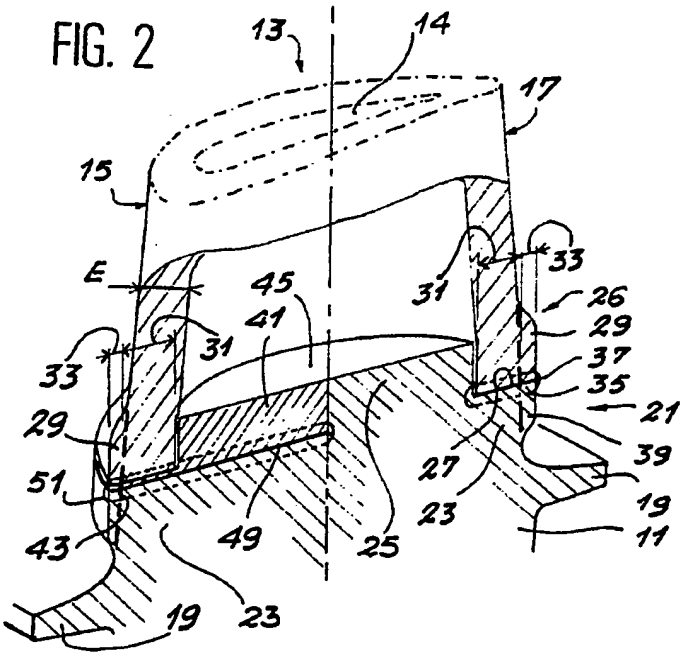

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FIG. 1

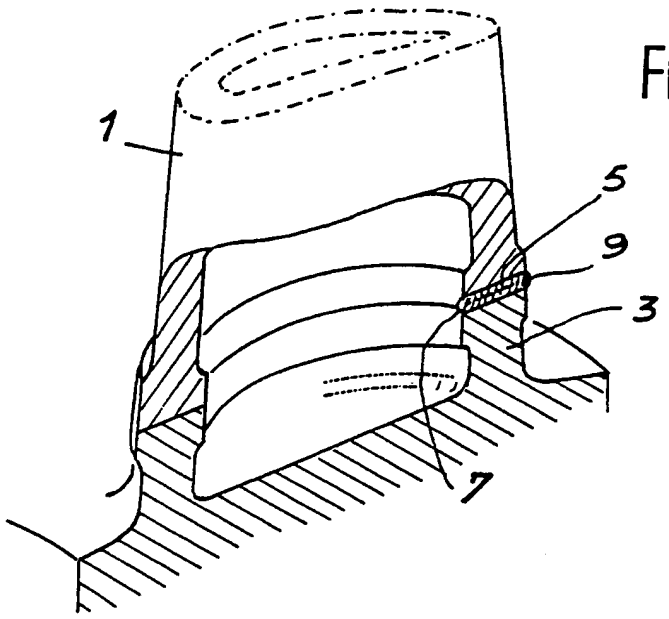


FIG. 3

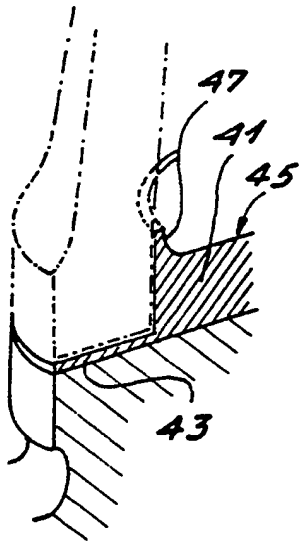
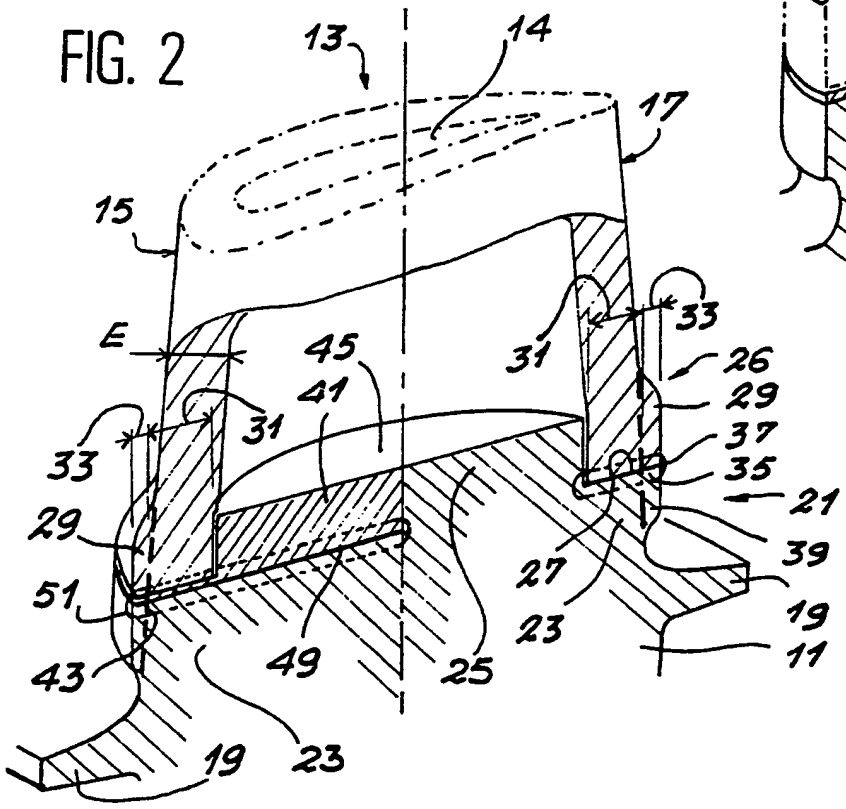


FIG. 2



UNITARY ROTORS HAVING HOLLOW BLADES, AND THE MANUFACTURE OF SUCH ROTORS

The invention relates to a process for the manufacture of a unitary rotor having hollow blades, and to a unitary rotor produced thereby. Such rotors are particularly suitable for use in low pressure compressors.

In the field of low pressure compressors for turbojet engines, research work has been carried out into making the rotors of such compressors lighter. These rotors are mainly of unitary construction and are known in English terminology as a "blisk", which is a contraction of "bladed disk". The rotors are unitary in that the blades are an integral part of the hub, or are connected with it, as opposed to rotors of the "winged disk" type in which the blades are provided with roots which engage in cells machined in the periphery of the hub, before being locked into the cells.

To lighten rotors of the "blisk" type, two solutions have been studied. A first solution involves machining the blading from a blank, i.e. the blades are produced *in situ* on the periphery of the disc by machining the blade profiles. The latter are, therefore, an integral part of the hub. They are subsequently hollowed also by

machining. However, this solution is difficult to implement because of the small thickness of the blades and their complex helical shape. This solution is thus far too costly to be adopted industrially.

A second solution involves first shaping and hollowing blades by machining, and only then connecting them to the hub by a suitable method such as welding or brazing. This solution, which is easier and less costly to implement industrially, has been adopted.

Various methods for fixing blades to a hub are already known.

FR-A-2 602 266 discloses a process for the manufacture of a rotor assembly for a gas turbine engine, in which a disc is made with two outer annular flanges, a ring of vanes is also made with two annular flanges, and the ring of vanes is then assembled on the disc in the hot state. The vanes are then sealed under vacuum and the assembly is subjected to an isostatic compression in the hot state.

However, this process can be used only with solid blades or, at least, with blades which have a solid base and two side flanges, as it involves crushing the two faces of the flanges of the blades with those of the disc, so as

to form a continuous connection. This process does not permit correct fixing of hollow blades in which the cavity opens out at the base of the blade.

EP-A-0 458 630 discloses a process for fixing individual blades on the disc of a rotor of the "blisk" type. This process is applicable to solid blades which are held between the two jaws of a fixing device and are connected to the disc by a friction connection operation, and is also applicable to the repair of blades.

US-A-4 034 182 discloses a process which involves assembling at their lateral sides a series of slightly concave segments each carrying on its outer surface a compressor vane, so as to form a ring fitted with radial blades. However, this process is difficult to apply to the manufacture of "blisk" type rotors with hollow blades.

FR-A-2 619 331 discloses a process for the manufacture of a rotor with integral fins, especially for a gas turbine engine, and concerns the fixing of solid blades on the disc of the rotor. It comprises the steps of forming a cavity in a part constituting the root of each fin, forming a plurality of cubic projections on the periphery of the rotor disc, and then assembling each fin on the disc by a nesting process. The fixing proper is effected

by pressure and heating. This connection is realised principally between the upper face of the cubic projection and the bottom of the cavity provided in the fin. It is possible subsequently to carry out machining so as to remove the parts of the fin which define the lateral parts of the cavity. This type of process cannot however be used for fixing blades which are hollow throughout their height, since the end surface of the cubic projection cannot come to rest against the bottom of the fin cavity.

Finally, and as illustrated in Figure 1, when a hollow blade 1 is welded in a conventional manner on a disc 3 of a rotor, the welding band 5 which is formed presents a weld bead 7 inside the hollow blade and a bead 9 on the outside of the blade. However, it is impossible to effect the mechanical removal of the internal bead 7 because of the very small thickness of the blade 1 and its helical geometry. Consequently, the inner surface condition of the blade is not compatible with the non-destructive verification tests (X-ray photography, ultrasonic tests, etc.) which are imperative to meet the demands of the aeronautics industry.

With the aim of overcoming these drawbacks, according to the invention there is provided a process for the

manufacture of a unitary rotor having hollow blades, comprising the steps of providing a rotor disc with projections on its periphery at the positions where the blades are to be fixed to the disc, each projection having an outline shape which substantially corresponds to that of the inside of each blade at the radially inner end of the blade and having its periphery surrounded by a flat joint surface, fitting the radially inner end of each hollow blade over a respective one of the projections, and fixing each blade to the rotor disc by welding the radially inner end surface of the blade defined by the thickness of the walls of the blade to the flat joint surface surrounding the projection.

Owing to the presence of the projection which fits into the inner end of each blade the welding band cannot extend into the inside of the blade to form an inner bead. In addition, there is no possibility of suppression of the ends of the welding as there is no internal bead.

Moreover, this process in which the blades are fitted to the end of the disc enables production costs to be reduced as the machining of the disc and the blades is carried out in separate operations.

Finally, the process is also applicable to the repair of a damaged blade, which can simply be replaced by a new blade.

The invention also provides a unitary rotor of the type comprising a disc and a plurality of hollow blades fixed on the periphery of the disc, in which each blade is fixed to a protuberance which is integrally cast with the disc and has a projection which fits into the radially inner end of the hollow blade, the protuberance defining a shoulder which surrounds the projection and forms a flat joint surface to which the inner end surface of the blade is welded.

The invention further provides an alternative embodiment in the form of a unitary rotor of the type comprising a disc and a plurality of hollow blades fixed on the periphery of the disc, in which the periphery of the disc has a protuberance in line with each blade, and a block is welded to each protuberance, the block forming a projection which fits into the radially inner end of the respective hollow blade and having a thin flat peripheral flange surrounding the projection at its radially inner edge to define a flat joint surface to which the inner end surface of the blade is welded.

Embodiments of a unitary rotor in accordance with the invention, and their manufacture, will now be described, by way of example only, with reference to the attached drawings, in which:

Figure 1 is a diagrammatic sectional view of part of a unitary rotor having hollow blades fixed on a rotor disc by a known method;

Figure 2 is a diagrammatic sectional view similar to Figure 1 but illustrating the rotor constructions resulting from two different embodiments of the manfuacturing process in accordance with the invention; and,

Figure 3 is a detailed view of a part of Figure 2.

As shown in Figure 2, the rotor formed by the process in accordance with the invention is a unitary rotor of the "blisk" type having hollow blades. The rotor comprises a disc 11, seen in part cross-section in Figure 2, and a plurality of hollow blades 13 evenly distributed around the periphery of the disc, only part of one of which is shown in the drawing. For the sake of a purely illustrative example, a disc may have thirty-six blades evenly distributed over its periphery.

The hollow blade 13 is of a conventional slightly twisted form, its central cavity being denoted at 14, its leading edge at 15, and its trailing edge at 17.

A first embodiment of the invention will now be described with reference to the right-hand half of Figure 2.

The disc 11 is provided on its two side faces and at the periphery thereof with a continuous fin 19. In the course of the manufacture of the disc 11 projecting means, generally denoted by 21, are formed on its periphery at the positions where the blades 13 are to be fixed. These projecting means 21 comprise protuberances 23 which are integrally cast with the disc, and integral projections 25 on the protuberances. Each pojection 25 is a block having a shape which corresponds substantially to that of the inside of the cavity 14 of the blade at its radially inner end 26, i.e. at the foot of the blade. The projection 25 therefore has a slightly concave elongated shape. The projection 25 is dimensioned to be slightly smaller than the protuberance 23 on which it is formed, so that the two define a shoulder forming a substantially flat joint surface 27 on the protuberance extending continuously around the projection 25. In view of the relatively thin and elongated shape of the projection 25 in the type of rotor

represented here, the joint surface 27 has substantially the shape of a flattened ring.

Advantageously, the radially inner end 26 of each hollow blade 13 is provided externally with a peripheral collar 29. This peripheral collar 29 acts to reinforce the thickness at the base of the hollow blade which is fixed on the disc, but its precise role will be explained later.

In the course of assembly, each blade 13 is fitted over a respective projection 25 of the disc 11 until the end surface 31,33 defined by the combined thickness of the wall of the blade and the collar 29 contacts the flat joint surface 27 of the disc. Each blade 13 is then fixed to the disc 11 by welding, the term "welding" also covering brazing. The welding may be electron beam welding, diffusion welding, brazing, diffusion brazing, electrical discharge welding or laser welding for example.

The walls of the hollow blades 13 have a small thickness (thickness E close to 10mm) and thus the weld band 35 extends between the surfaces 31,33 and 27, but the presence of the projection 25 prevents the formation of a weld bead on the inside of the blade 13. It is therefore unnecessary to carry out any further machining inside the blade. On the other hand an external weld bead 37 is

formed by the weld band 35, and this is removed by machining. The collar 29 and the corresponding part 39 of the protuberance 23 are also removed by this machining. In this way, perfect surface continuity is obtained between the disc 11 and the blade 13, this machined surface being indicated in Figure 2 by means of the dashed line.

In a simplified version wherein the blade 13 does not include a collar 29, only the outer bead 37 is removed by the machining.

A second method of implementing the manufacturing process in accordance with the invention is illustrated in the left-hand portion of Figure 2. In this method the projecting means 21 comprise protuberances 23 which are integral with the disc as in the first embodiment, but the projections 25 are formed by blocks 41 formed independently of the disc 11. The outline shape of each block 41 corresponds substantially to that of the inside of the blade cavity 14 at its radially inner end 26, so as to be able to fit inside it. Also, each block 41 is formed with a flat and extremely thin peripheral flange 43 at its radially inner edge providing a flat peripheral joint surface similar to the joint surface 27. This is best seen in the detailed view of Figure 3.

In addition, the block 41 may advantageously have, on its face 45 facing into the cavity 14, a peripheral upstand 47 extending radially outwards around the entire edge of the face 45.

During the manufacture of the disc 11 its periphery is formed only with the protuberances 23. The projections formed by the blocks 41 and the flanges 43 are then set in place on the protuberances 23, and the blades 13 are nested on the blocks 41. The blades 13, the disc 11 and the blocks 41 are then welded together, for example, using one of the welding processes previously mentioned.

As the thickness of each blade 13 is rather low (thickness E close to 10mm), the weld or brazing band passes through the inner walls of the blade and reaches the block 41. Thus the welding (fixing) is effected, on the one hand, between the flange 43 and the end surface 31,33 of the blade corresponding to the combined thickness of the blade wall and the collar 29, and on the other hand between the flange 43 and the protuberance 23 of the disc. The welding is also effected between the block 41 and the prouberance 23. The welding band is indicated at 49 in Figure 2.

The presence of the block 41, and particularly the

upstand 47, prevents the entry of the weld band into the cavity 14 and hence prevents the formtion of a weld bead within the cavity.

The external weld bead 51 which is formed is removed by machining in the same way as the bead 37 in the first embodiment.

CLAIMS

1. A process for the manufacture of a unitary rotor having hollow blades, comprising the steps of providing a rotor disc with projections on its periphery at the positions where the blades are to be fixed to the disc, each projection having an outline shape which substantially corresponds to that of the inside of each blade at the radially inner end of the blade and having its periphery surrounded by a flat joint surface, fitting the radially inner end of each hollow blade over a respective one of the projections, and fixing each blade to the rotor disc by welding the radially inner end surface of the blade defined by the thickness of the walls of the blade to the flat joint surface surrounding the projection.

2. A process according to claim 1, in which each projection is formed by part of a protuberance on the periphery of the rotor disc and cast integrally with the disc, the protuberance defining a shoulder which surrounds the projection and forms the flat joint surface.

3. A process according to claim 1, in which each projection is formed by a block which has a surrounding thin flat flange at its radially inner edge defining the

flat joint surface, and the block is welded to the rotor disc at the same time as the respective blade is welded to the flat joint surface defined by the flange.

4. A process according to claim 1, in which the external weld bead formed by the welding of the blade to the flat joint surface is removed by machining.

5. A process according to any one of claims 1 to 3, in which the radially inner end of each blade is surrounded by a collar and, after the blade has been fixed to the rotor disc by welding, the resulting external weld bead is removed by machining, along with the collar and a part of the disc and the flat joint surface.

6. A process according to claim 1, in which the welding method used is electron beam welding, diffusion welding, brazing, diffusion brazing, electrical discharge welding, or laser welding.

7. A unitary rotor of the type comprising a disc and a plurality of hollow blades fixed on the periphery of the disc, in which each blade is fixed to a protuberance which is integrally cast with the disc and has a projection which fits into the radially inner end of the hollow blade, the protuberance defining a shoulder which

surrounds the projection and forms a flat joint surface to which the inner end surface of the blade is welded.

8. A unitary rotor of the type comprising a disc and a plurality of hollow blades fixed on the periphery of the disc, in which the periphery of the disc has a protuberance in line with each blade, and a block is welded to each protuberance, the block forming a projection which fits into the radially inner end of the respective hollow blade and having a thin flat peripheral flange surrounding the projection at its radially inner edge to define a flat joint surface to which the inner end surface of the blade is welded.

9. A process according to claim 1, substantially as described with reference to Figure 2 or Figure 3 of the accompanying drawings.

10. A unitary rotor according to claim 7 or claim 8, substantially as described with reference to Figure 2 or Figure 3 of the accompanying drawings.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report) -16-	Application number GB 9400072.6
Relevant Technical Fields (i) UK Cl (Ed.M) B3R; RWB; RWW; RBC; RSC; F1V; VCQ (ii) Int Cl (Ed.5) B23K, F01D, F04D	Search Examiner D N P BUTTERS Date of completion of Search 30 MARCH 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1-10

Categories of documents

X:	Document indicating lack of novelty or of inventive step.	**P:**	Document published on or after the declared priority date but before the filing date of the present application.
Y:	Document indicating lack of inventive step if combined with one or more other documents of the same category.	**E:**	Patent document published on or after, but with priority date earlier than, the filing date of the present application.
A:	Document indicating technological background and/or state of the art.	**&:**	Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1468301	(HITACHI)	1, 2, 6, 7
X	EP 0212921	(WESTINGHOUSE) See Figure 3	1, 2, 4, 5, 7

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